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Physics Department, Carnegie-Mellon University
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W. T. Oosterhuis and J. P. Stampfel

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13. ABSTRACT

Mossbauer effect experiments in single crystal $FeCl_3$ (anhydrous) show the hyperfine field to vary with temperature according to $H(T) = H_0(1-T/TN)^{\beta}$ where $\beta = 0.14$ which is indicative of two dimensional magnetic ordering. Further experiments show a spin reorientation for fields of about 40 kiloOersted applied along the c-axis. The boundaries of the magnetic phases in the H-T plane are determined.

$H(T) = H(0)(1-T/TN)$

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Security Classification

MAGNETIC PHASES IN A TWO DIMENSIONAL ANTIFERROMAGNET*

W. T. Oosterhuis and J. P. Stampfel
Physics Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

Anhydrous ferric chloride ($FeCl_3$) has been studied under varying conditions of temperature and applied magnetic field using nuclear gamma ray resonance (Mössbauer Effect). The Fe^{3+} ions occupy interstices of a hexagonal close packed lattice of Cl^- ions and form a honeycomb arrangement in planes perpendicular to the (hexagonal) c-axis. Single crystals of $FeCl_3$ were grown from the melt (285 C) and absorbers suitable for transmission experiments were cleaved perpendicular to the c-axis. Attempts to cut slices in other directions resulted in multiple fractures.

Below a critical temperature of 8.7 K the iron ions become antiferromagnetically ordered with a complicated helical spin structure in zero applied field.

Experiments done in the absence of an applied magnetic field show a rapid increase in the hyperfine field as the temperature is lowered through the Neél point. As seen in Fig. 1 the thermal behavior of the hyperfine field H(T) is fairly well represented for all temperatures less than T_N by the expression

$$H(T) = H_0 D(1 - T/T_N)^{\beta}$$

T_N = 8.7 K is the Neél temperature, H_0 = 495 kOe is the saturation hyperfine field, D = 1.02, and β = 0.146 is the critical exponent. The value obtained for the saturation hyperfine field is relatively small compared to that found for most ionic ferric ions. It is most likely that covalent sharing of the magnetic electrons is the major source of the reduction. It is generally agreed that the critical exponent β gives an indication of the dimensionality of the magnetic ordering. It is well known that a value of $\beta = 1/8 = 0.125$ is expected for systems which exhibit two-dimensional behavior whereas $\beta = 1/3$ is typical for three dimensional systems. The behavior of the hyperfine field is shown in Fig. 1 where it is apparent that the data for $FeCl_3$ falls near the curve calculated with $\beta = 0.146$. We thus make the conjecture that the magnetic order exists in layers.

When a magnetic field is applied in the c-direction, it adds vectorially to the hyperfine field and a distribution of effective fields are seen by the nuclei. This is seen in the broadened lines of the Mössbauer spectrum. The magnetic moments and thus the hyperfine fields of the Fe^{3+} ions are probably rotated themselves because of the applied field. In the neighborhood of 40 kOe a spin reorientation takes place as indicated by the sudden increase in the intensities of the $\Delta m = 0$ transitions. Each magnetic site experiences the same effective field above the spin flop field as evidenced by the narrow lines in the spectrum. We have done experiments to determine this boundary between the magnetic phases in the H-T plane with the results shown in Fig. 2. In addition the boundaries between the paramagnetic and ordered phases below 60 kOe have been determined. The boundaries are only known to within a few percent, but the present results may provide a starting point for a technique better suited to that purpose.

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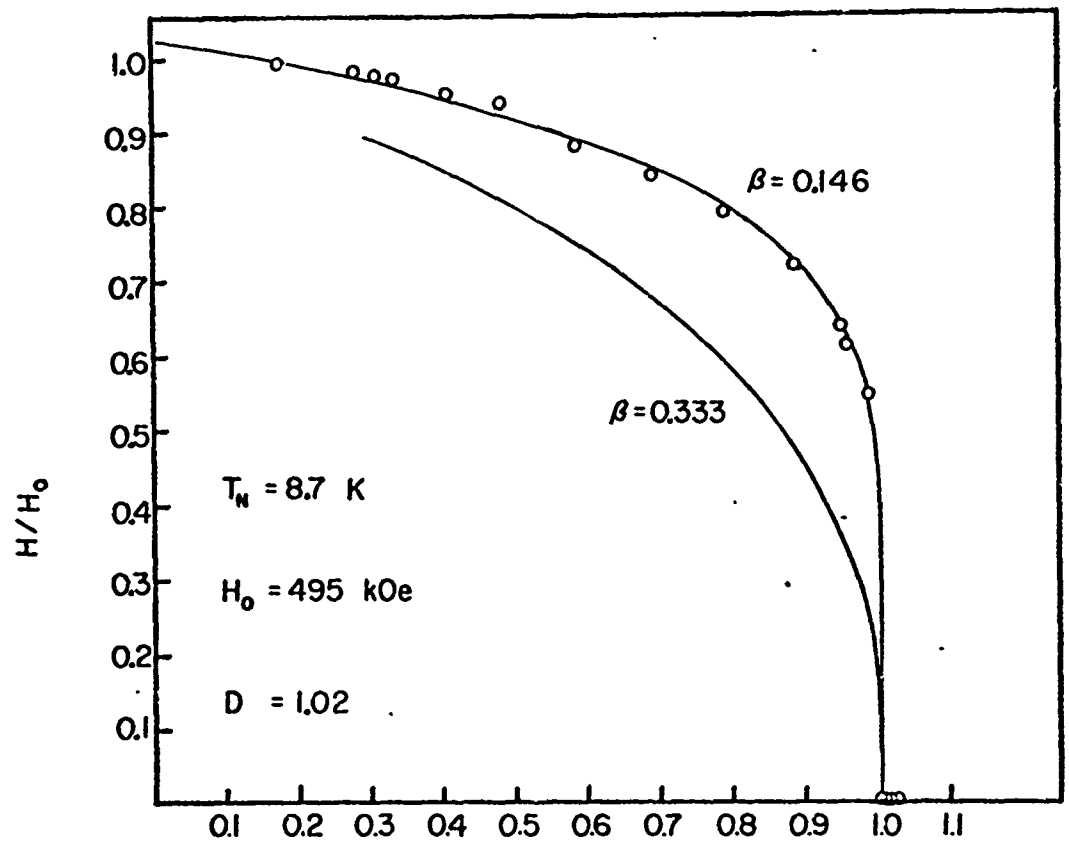
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
H/H₀
β = 0.146
β = 0.333
T_N = 8.7 K
H₀ = 495 kOe
D = 1.02
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
T/T_N

Fig. 1

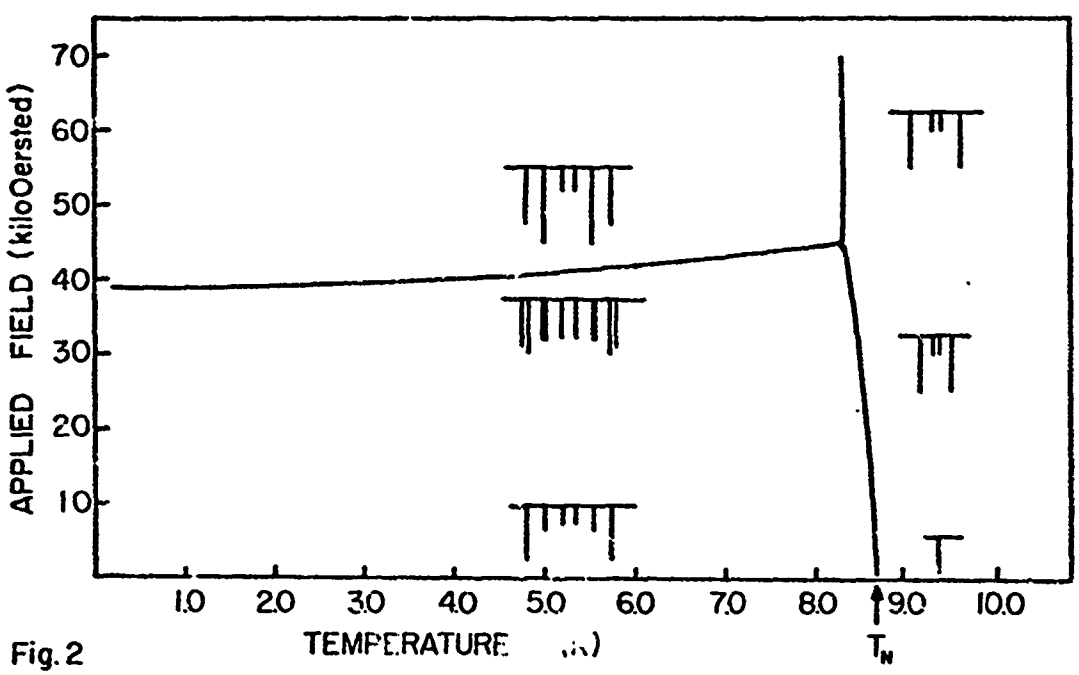
70
60
50
40
30
20
10
APPLIED FIELD (kiloOersted)
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
TEMPERATURE (K)
T_N

Fig. 2